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# EXPERIMENTS ON THE DIGESTIBILITY OF FISH.[1]

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## INTRODUCTION.

While many studies have been made of the digestibility of milk, cereals, fats, vegetables, and meats (especially beef), less information is available regarding the digestibility of fish. Slowzoff[2] has reported experiments with six persons in which fish was substituted for meat in an otherwise uniform diet to determine its effect on the metabolism of phosphorus, calcium, and magnesium. He found no change in the metabolism of phosphorus; the absorption of calcium was diminished 5 per cent, and the absorption of magnesium was increased 8 per cent. Kïi͡anitsyn[3] found that the protein supplied by salt cod was 90 per cent digested by human subjects when the fish was eaten alone and 94.4 per cent digested when eaten as a part of a mixed diet. Rozov,[4] in a study of the relative digestibility of the fat of smoked and fresh smelt, found that it was 98 per cent utilized in the smoked and 97 per cent in the fresh. Slowzoff and Krawtschenko[5] report

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[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

[2] Verhandl. Gesell. Russ. Arzte St. Petersb., 76 (1909), p. 220.

[3] Nutritive Value of the Cod. Diss., Imp. Mil. Med. Acad. [St. Petersb.], 1887, pp. 56. [Russian.]

[4] Comparative Assimilation of Fats from Fresh and Smoked Fish. Diss., Imp. Mil. Med. Acad.[ St. Petersb.], 1891, pp. 48. [Russian.]

[5] Verhandl. Gesell. Russ. Arzte St. Petersb., 1907–8; abs. in Zentbl. Gesam. Physiol. u. Path. Stoffwechsels, n. ser., 4 (1909), No. 1, p. 40.

NOTE.—This bulletin records studies of the digestibility of Boston mackerel, butterfish, grayfish, and salmon, and is primarily of interest to students and investigators of food problems.

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that the absorption of mineral salts is better on a diet containing fresh or salt fish and poorer on a diet containing dried fish than on a diet containing beef. Van Slyke and White,[1] using the rate of excretion of nitrogen in the urine as an index of the rate of protein digestion, found that boiled cod (fresh) was more rapidly digested than boiled beef, boiled weakfish, boiled mussel, and boiled cod (salt). Rosenfeld,[2] in a study of the nutritive value of fish (sea pike and sea salmon), concludes that fish causes the excretion of a smaller amount of uric acid than meat and that fish is equal to beef for maintaining nitrogen equilibrium. In digestion experiments with beef and fish, Atwater[3] compared the amounts of protein, fat, and ash assimilated, and obtained the same coefficients of digestibility for both food materials.

Studies of the digestibility of canned salmon have been reported by Milner,[4] who found in four experiments in which an average of 401 grams of salmon was eaten daily for three days with a simple mixed basal ration consisting of bread, milk, butter, and sugar, that 96 per cent of the protein and 97 per cent of the fat of the salmon were retained by the body.

A number of other investigators have studied the value of fish flesh for food purposes by means of artificial digestion experiments. Hönigsberg[5] studied the relative digestibility of fish and found that pepsin digested whitefish protein more rapidly than raw and less rapidly than cooked beef. In a study of the digestibility of fish protein by trypsin, White and Crozier[6] found that boiled codfish and dogfish digested more readily than boiled beef. Sulima[7] conducted experiments to determine whether there were differences in food in the raw state and that cooked at a high temperature which would affect the digestive process and concluded that gastric digestion was much slower with cooked than with uncooked fish (sardines). This difference, he believed, was due to the enzyms present in the raw fish. König and Spittgerber,[8] as a result of determinations of the composition, energy value, and constants of fish fat, and a study of the digestibility of fish flesh by means of artificial digestion experiments, concluded that fish flesh is as easily and completely digested as meat.

In the earliest elaborate series of investigations of food materials made in this country, Atwater[9] studied the composition of fish, and the results of this investigation contributed largely to the general knowledge of the food value of fish and its importance as a source of fat and other nutrients in the diet. The results of his studies[1] of 50 or more varieties showed that, on an average, fish contains over 18 per cent of protein, and about 4 per cent of fat. Generalizing from these data it has been pointed out[2] that fish may be divided on the basis of their fat content into three classes: Those with over 5 per cent fat such as shad, salmon, butterfish, and herring; those containing from 2 to 5 per cent fat such as whitefish, halibut, and porgy; and those containing less than 2 per cent fat such as bluefish, haddock, and cod. It is evident that fish, like meat, may contribute materially to the fat of the diet, particularly if the fatter varieties are eaten. On the basis of the protein they supply they also resemble meat, and this is true too with respect to the ways in which they are used in the diet. Accordingly, fish should be considered as a protein food and classed with the meats. However, notwithstanding the fact that protein is essential in the diet and fat is supplied in a readily assimilated form in fish, the use of fish is small in comparison with the use of beef, pork, and mutton, which are also sources of animal protein. The demand for land animal "meats" is at present in excess of the supply, while the possible supply of fish is believed to be much greater than the present demand.

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[1] Jour. Biol. Chem., 9 (1911), No. 3-4, pp. 219-229.

[2] Zentbl. Inn. Med., 27 (1906), No. 7, pp. 169-176.

[3] Ztschr. Biol., 24 (1888), No. 1, pp. 16-28; abs. in Jahresber. Tier Chem., 17 (1887), p. 418.

[4] Connecticut Storrs Sta. Rpt. 1905, p. 142.

[5] Wiener Med. Bl., 5 (1882), Nos. 19, pp. 582-585; 20, pp. 614-616.

[6] Jour. Amer. Chem. Soc., 33 (1911), No. 12, pp. 2042-2048.

[7] Arch. Hyg., 75 (1912), No. 6-7, pp. 235-264.

[8] Landw. Jahrb., 38 (1909), Sup. 4, pp. 1-169.

[9] U. S. Comr. Fish and Fisheries Rpt. 1883, pp. 423-494.

In view of the attempts which are being made to interest the public in methods of reducing the consumption of meat without lessening the nutritive value and attractiveness of the diet, definite knowledge of the food value of fish is of especial importance. And so, as part of the studies of the food value and uses of fish in the home, which are being undertaken, it seemed desirable to study the digestibility of some varieties of fish taken to be representative of general types, including some which are well known and one, grayfish, which is comparatively new in the American market.

## DIGESTION EXPERIMENTS WITH MEN.

Seven young men (medical and dental students) who had gained experience in other investigations of like character, served as subjects in this investigation. They were all normal individuals of good health, and reasonably active. During the experimental period they were requested to observe their usual routine as regards amount of exercise taken, hours of eating, etc. From their knowledge of physiology and previous experience in this type of work, they were sufficiently informed of the nature of their duties to appreciate the importance of carefully following the directions given them.

For the purpose of this investigation a special fore period and after period were not considered necessary, and accordingly the subjects were allowed to follow their customary dietary routine preceding and following the experimental period. For the purpose of identifying the feces of the experimental period, three or four gelatin capsules containing about 0.3 gram of pulverized charcoal were taken with the first meal of the experimental period and with the first meal following it; the separation of the feces due to the diet under investigation was easily made at the lines of demarcation made by the portions dully colored by the charcoal.

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[1] Loc. cit. and U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906), rev. ed., pp. 45–50.

[2] U. S. Dept. Agr., Farmers' Bul. 85 (1898), p. 14.

Inasmuch as this study is concerned principally with the coefficient of digestibility of the protein and fat of the fish, no attempt was made to maintain a nitrogen equilibrium or uniform body weight of the subjects. The urine resulting from the experimental periods was not collected, for it was considered that any constituents of the foods which had been sufficiently broken down to appear in the urine had undergone the process of digestion; furthermore, the results obtained by collecting and analyzing the urine of a short test period are not entirely conclusive since the urine can not be separated as satisfactorily as the feces.

## PREPARATION OF FISH.

In this study of the digestibility of different types of fish, fresh butterfish and Boston mackerel were used, and canned grayfish and canned salmon. A fish loaf seemed to be the best form in which to prepare the fish for eating, since sufficient quantities for the entire experimental period could be prepared at one time. Furthermore, it was easy to prepare a fish loaf having a uniform composition and one which would not change materially on standing by the settling out of fat or evaporation of water.

The butterfish and mackerel received a preliminary cooking before being incorporated in the fish loaf. The fish, after being cleaned, were thoroughly washed and placed as close as possible to each other in a covered cooker, water was added, and they were cooked for one-half hour. They were not boiled, but steamed in a very small quantity of water which prevented browning or sticking to the pan. To prevent any loss due to extracted fat and protein, the water in which the fish were steamed was retained and mixed with the fish meat, Beythien[1] having reported that the water in which fish were boiled contained 8.8 to 11.3 per cent of the total fish protein. After this preliminary cooking of the butterfish and mackerel, the bones, any pieces of fins, etc., were removed and the fish meat was cut in an ordinary household meat cutter. The bones and bits of skin were removed from the canned grayfish and salmon, and the solid meat was minced in a meat cutter. From this point the preparation of the fish loaf was identical for the canned and fresh fish. In each instance a quantity of the fish to be studied sufficient for the entire test period, after being mixed with salt and pepper, was very thoroughly and uniformly mixed and baked for two to three hours in a moderate oven. Whatever crust formed during baking was removed, and the remaining portion was again thoroughly mixed in order to secure a uniform product, after which a sample was taken for analysis.

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[1] Pharm. Centralhalle, 47 (1906), p. 140.

## NATURE OF THE DIET.

Inasmuch as experience has shown that in studying the digestibility of a single food it is desirable to supply the food material under consideration as a part of a simple mixed diet, a suitable basal ration was served with the fish loaf. It consisted of boiled potatoes, crackers, apple sauce, sugar, tea or coffee, and a little lemon juice as a condiment in some cases. In accordance with the usual custom, a sufficient supply of the special food under consideration (fish loaf) and of the other foods was prepared in advance for the whole experimental period. The fish loaf was kept in a refrigerator at 15° C. and remained fresh and in good condition, as did also the potatoes, which were boiled, mashed, and thoroughly mixed to insure uniform composition. The apples, which were eaten raw, were of good grade and pleasant flavor. The crackers or "biscuits" used were taken from a large lot and assumed to be of uniform composition. Though no attempt was made to have all eat like amounts, the subjects were urged to eat liberally of the fish loaf and moderately of the crackers and potatoes, following their individual preferences with respect to the apples and the tea or coffee.

As a whole, the ration, though it contained no added fat and only moderate amounts of carbohydrates, was reasonably generous as regards protein and energy and was varied enough not to become tiresome.

The food for each man for each meal was weighed in advance and kept separate. All remaining uneaten was weighed. The difference between the amount furnished and the amount remaining represented the amount eaten.

Samples of the food were reserved for analysis. The small amount of lemon juice (on an average, 35 grams per day), which was eaten with the butterfish and the Boston mackerel, was disregarded in computing the food value of the diet.

The feces were collected, sampled, and analyzed by the methods followed in the department's digestion experiments, of which the present investigation forms a part.[1]

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[1] U. S. Dept. Agr. Bul. 310 (1915), pp. 23. See list on last page.

## BOSTON MACKEREL.

The investigations reported in this paper, which form a part of an extended study of the digestibility, nutritive value, and uses in the home of fish and fish products, have to do particularly with the digestibility of protein. One of the varieties of fish, Boston mackerel, here studied in comparison with other sorts of fish, has, however, been considered from the standpoint of the relative digestibility of animal fats of different kinds in an earlier bulletin.[1]

Boston mackerel (*Scomber scombrus*, Linnæus) is a highly flavored fish, which can be compared to moderately fat meat in food value, since it supplies good amounts of both protein and fat. This fish, which is found throughout the north Atlantic, spends the winter months in deep water; in the spring, schools rise to the surface and approach the land. This fish forms one of the chief products of the New England fisheries, the catch during the year 1916 amounting to approximately 16,000,000 pounds. The fish used in this investigation were purchased at a local market and weighed, after cleaning, approximately 3 pounds each. They were procured at the height of the season, were in prime condition, and when prepared in the form of a fish loaf made a most appetizing dish. While the Boston mackerel possesses a characteristic flavor which is quite pronounced in the boiled or fried fish, this flavor was not evident in the fish loaf.

Three subjects living under normal conditions, who had acquired considerable experience in work of this kind in connection with the determination of the digestibility of some of the common edible fats of animal and vegetable origin, assisted in this study. The results which were obtained in the three-day test period follow.

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[1] U. S. Dept. Agr. Bul. 507 (1917), p. 16.

*Data of digestion experiments with Boston mackerel in a simple mixed diet.*

| Experiment, subject, and diet. | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbo-hydrates. | Ash. |
| Experiment No. 444, subject D. G. G.: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Boston mackerel (in form of fish loaf) | 1,496.0 | 926.0 | 323.0 | 199.9 | ........ | 47.1 |
| Potato | 439.0 | 331.5 | 11.0 | .4 | 91.7 | 4.4 |
| Crackers | 284.0 | 19.6 | 23.0 | 38.0 | 201.1 | 2.3 |
| Fruit | 1,320.0 | 1,116.7 | 5.3 | 6.6 | 187.4 | 4.0 |
| Sugar | 171.0 | ........ | ........ | ........ | 171.0 | ........ |
| Total food consumed | 3,710.0 | 2,393.8 | 362.3 | 244.9 | 651.2 | 57.8 |
| Feces | 67.0 | ........ | 19.3 | 10.1 | 31.9 | 5.7 |
| Amount utilized | ........ | ........ | 343.0 | 234.8 | 619.3 | 52.1 |
| Per cent utilized | ........ | ........ | 94.7 | 95.9 | 95.1 | 90.1 |
| Experiment No. 446, subject R. L. S.: | | | | | | |
| Boston mackerel (in form of fish loaf) | 1,184.0 | 732.9 | 255.6 | 158.2 | ........ | 37.3 |
| Potato | 227.0 | 171.4 | 5.7 | .2 | 47.4 | 2.3 |
| Crackers | 243.0 | 16.8 | 19.7 | 32.6 | 172.0 | 1.9 |
| Fruit | 1,376.0 | 1,164.1 | 5.5 | 6.9 | 195.4 | 4.1 |
| Sugar | 58.0 | ........ | ........ | ........ | 58.0 | ........ |
| Total food consumed | 3,088.0 | 2,085.2 | 286.5 | 197.9 | 472.8 | 45.6 |
| Feces | 53.0 | ........ | 21.9 | 7.5 | 16.2 | 7.4 |
| Amount utilized | ........ | ........ | 264.6 | 190.4 | 456.6 | 38.2 |
| Per cent utilized | ........ | ........ | 92.4 | 96.2 | 96.6 | 83.8 |
| Experiment No. 447, subject O. E. S.: | | | | | | |
| Boston mackerel (in form of fish loaf) | 1,348.0 | 834.4 | 291.0 | 180.1 | ........ | 42.5 |
| Potato | 476.0 | 359.4 | 11.9 | .5 | 99.5 | 4.7 |
| Crackers | 171.0 | 11.8 | 13.8 | 22.9 | 121.1 | 1.4 |
| Fruit | 1,594.0 | 1,348.5 | 6.4 | 8.0 | 226.3 | 4.8 |
| Sugar | 165.0 | ........ | ........ | ........ | 165.0 | ........ |
| Total food consumed | 3,754.0 | 2,554.1 | 323.1 | 211.5 | 611.9 | 53.4 |
| Feces | 70.0 | ........ | 28.6 | 12.2 | 21.6 | 7.6 |
| Amount utilized | ........ | ........ | 294.5 | 199.3 | 590.3 | 45.8 |
| Per cent utilized | ........ | ........ | 91.1 | 94.2 | 96.5 | 85.8 |
| Average food consumed per subject per day | 1,172.4 | 781.4 | 108.0 | 72.7 | 192.9 | 17.4 |

*Summary of digestion experiments with Boston mackerel in a simple mixed diet.*

| Experiment No. | Subject. | Protein. | Fat. | Carbo-hydrates. | Ash. |
|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 444 | D. G. G | 94.7 | 95.9 | 95.1 | 90.1 |
| 446 | R. L. S | 92.4 | 96.2 | 96.6 | 83.8 |
| 447 | O. E. S | 91.1 | 94.2 | 96.5 | 85.8 |
| | Average | 92.7 | 95.4 | 96.1 | 86.6 |

An average of 108 grams of protein, 73 grams of fat, and 193 grams of carbohydrates was consumed per man daily during the test periods with Boston mackerel, the fuel value of the diet being 1,861 calories. These constituents were found to be 92.7 per cent, 95.4 per cent, and 96.1 per cent digested, respectively. The coefficients of digestibility for the fish protein and fat were found to be 93.1 per cent and 95.2 per cent, respectively, when allowance was made for the undigested protein and fat resulting from the basal ration.

## BUTTERFISH.

Butterfish (*Poronotus triacanthus*) was chosen for one series of studies as an excellent fish of the type commonly used as pan fish. Butterfish occurs on the Atlantic and Gulf coasts from Maine to Texas, and during the year 1915 the catch of the coastal fisheries of New York and New Jersey amounted to over 5,000,000 pounds. At times it is taken in such abundance that a glut in the market results, and, since this fish is usually sold fresh, great quantities are wasted. The butterfish which was studied in the experiments here reported was of a good commercial grade, purchased in the local market, and it was believed to be representative of this type of fish procured under the ordinary trade conditions.

The three subjects who assisted in the study of the digestibility of butterfish, following the same routine which has hitherto proved entirely satisfactory, ate an average of 105 grams of protein, 37 grams of fat, and 208 grams of carbohydrates, daily, the fuel value of the diet being 1,585 calories. The data obtained for the three-day test period are included in the following table:

*Data of digestion experiments with butterfish in a simple mixed diet.*

| Experiment, subject, and diet. | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
| Experiment No. 452, subject D. G. G.: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Butterfish (in form of fish loaf) | 1,533.0 | 1,120.9 | 303.7 | 74.5 | | 33.9 |
| Potato | 115.0 | 86.8 | 2.9 | 0.1 | 24.0 | 1.2 |
| Crackers | 322.0 | 22.2 | 26.1 | 43.1 | 228.0 | 2.6 |
| Fruit | 1,259.0 | 1,065.1 | 5.0 | 6.3 | 178.8 | 3.8 |
| Sugar | 189.0 | | | | 189.0 | |
| Total food consumed | 3,418.0 | 2,295.0 | 337.7 | 124.0 | 619.8 | 41.5 |
| Feces | 46.0 | | 22.8 | 7.5 | 11.3 | 4.4 |
| Amount utilized | | | 314.9 | 116.5 | 608 5 | 37.1 |
| Per cent utilized | | | 93.2 | 94.0 | 98.2 | 89.4 |
| Experiment No. 454, subject R. L. S.: | | | | | | |
| Butterfish (in form of fish loaf) | 1,419.0 | 1,037.6 | 281.1 | 69.0 | | 31.3 |
| Potato | 139.0 | 104.9 | 3.5 | 0.1 | 29.1 | 1.4 |
| Crackers | 355.0 | 24.5 | 28.8 | 47.6 | 251.3 | 2.8 |
| Fruit | 1,423.0 | 1,203 8 | 5.7 | 7.1 | 202.1 | 4.3 |
| Sugar | 163 0 | | | | 163.0 | |
| Total food consumed | 3,499.0 | 2,370.8 | 319.1 | 123.8 | 645.5 | 39.8 |
| Feces | 60.0 | | 24.9 | 9.5 | 16.5 | 9.1 |
| Amount utilized | | | 294.2 | 114 3 | 629.0 | 30.7 |
| Per cent utilized | | | 92.2 | 92.3 | 97.4 | 77.1 |
| Experiment No. 455, subject O. E. S.: | | | | | | |
| Butterfish (in form of fish loaf) | 1,290.0 | 943.2 | 255.6 | 62.7 | | 28.5 |
| Potato | 569.0 | 429.6 | 14.2 | 0.6 | 118.9 | 5.7 |
| Crackers | 122.0 | 8.4 | 9.9 | 16.3 | 86.4 | 1.0 |
| Fruit | 1,474.0 | 1,247.0 | 5.9 | 7.4 | 209 3 | 4.4 |
| Sugar | 196.0 | | | | 196.0 | |
| Total food consumed | 3,651.0 | 2,628.2 | 285.6 | 87.0 | 610.6 | 39.6 |
| Feces | 68.0 | | 29.6 | 14.5 | 14.3 | 9.6 |
| Amount utilized | | | 256.0 | 72.5 | 596.3 | 30.0 |
| Per cent utilized | | | 89.6 | 83.3 | 97.7 | 75.8 |
| Average food consumed per subject per day | 1,174.2 | 810.5 | 104.7 | 37.2 | 208.4 | 13.4 |

*Summary of digestion experiments with butterfish in a simple mixed diet.*

| Experiment No. | Subject. | Protein. | Fat. | Carbohydrates. | Ash. |
|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 452 | D. G. G | 93.2 | 94.0 | 98.2 | 89.4 |
| 454 | R. L. S | 92.2 | 92.3 | 97.4 | 77.1 |
| 455 | O. E. S | 89.6 | 83.3 | 97.7 | 75.8 |
| | Average | 91.7 | 89.9 | 97.8 | 80.8 |

In the digestion experiments made with butterfish, the subjects ate an average of 471 grams of fish daily, which supplied 93 grams of protein and 23 grams of fat. The protein, fat, and carbohydrates of the total diet were found to be 91.7 per cent, 89.9 per cent, and 97.8 per cent digested, respectively. The values 91.7 per cent and 89.9 per cent for the digestibility of the protein and fat of the total diet become 91.9 per cent and 86.4 per cent, respectively, if allowance is made for the undigested protein and fat resulting from the basal ration. The estimated value, 86.4 per cent, for the digestibility of the fat of butterfish is somewhat lower than that of the other fish fats here reported. This lower value is no doubt in part due to the "heaping up of errors" involved in estimating the digestibility of a fat of a single food when it represents so small a portion of the total fat eaten. The subjects reported that they remained in normal physical condition during the experimental periods, except that subjects D. G. G. and O. E. S. reported that the diet produced a constipating effect, which was due, no doubt, to its very complete utilization.

## GRAYFISH.

The grayfish (*Squalus acanthias,* Linnæus), which is very abundant and easy to catch, though known to be wholesome, of good flavor, and usable for many appetizing dishes, has not been utilized to any extent in this country for food purposes, but has been considered largely as a source of oil and fish scrap, a fishery industry by-product of value for fertilizer material. Recently the Bureau of Fisheries has devoted considerable attention to the possible use of this fish in human nutrition and is of the opinion that it constitutes a cheap and very wholesome food.

In the literature consulted, no reports were found of the digestibility of grayfish. In order to judge of the value of the grayfish in the dietary, it seemed desirable to obtain information on this point, and, accordingly, tests were made in which canned grayfish was served in the form of a fish loaf in conjunction with the simple basal ration employed in the other tests reported in this paper. The canned fish used for this study was supplied by the Bureau of Fisheries and was taken to be representative of a large pack put up by a commercial concern under the direction of the Bureau of Fisheries.

Denis[1] in a study of the blood of a number of fishes found urea in the blood of the grayfish. An analysis of the canned grayfish showed that the flesh of this fish contained both ammoniacal and urea nitrogen. The amount of nitrogen present in this form is, however, relatively small, and when allowance was made in the experiments which follow for this nonprotein nitrogen it was found that the value for the coefficient of digestibility of protein was not materially changed.

Eight digestion experiments have been made with the grayfish and the results obtained for the three-day test period are reported in the following table:

*Data of digestion experiments with grayfish in a simple mixed diet.*

| Experiment, subject, and diet. | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
| **Experiment No. 535, subject H. R. G.:** | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Grayfish (in form of fish loaf) | 1,409.0 | 971.2 | 244.3 | 160.8 | | 32.7 |
| Potato | 486.0 | 366.9 | 12.1 | 0.5 | 101.6 | 4.9 |
| Crackers | 400.0 | 27.6 | 32.4 | 53.6 | 283.2 | 3.2 |
| Fruit | 581.0 | 491.5 | 2.3 | 2.9 | 82.5 | 1.8 |
| Sugar | | | | | | |
| Total food consumed | 2,876.0 | 1,857.2 | 291.1 | 217.8 | 467.3 | 42.6 |
| Feces | 64.0 | | 37.8 | 7.3 | 15.3 | 3.6 |
| Amount utilized | | | 253.3 | 210.5 | 452.0 | 39.0 |
| Per cent utilized | | | 87.0 | 96.6 | 96.7 | 91.5 |
| **Experiment No. 537, subject P. K.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,621.0 | 1,117.3 | 281.1 | 185.0 | | 37.6 |
| Potato | 507.0 | 382.8 | 12.7 | 0.5 | 105.9 | 5.1 |
| Crackers | 529.0 | 36.5 | 42.9 | 70.9 | 374.5 | 4.2 |
| Fruit | 890.0 | 752.9 | 3.6 | 4.4 | 126.4 | 2.7 |
| Sugar | | | | | | |
| Total food consumed | 3,547.0 | 2,289.5 | 340.3 | 260.8 | 606.8 | 49.6 |
| Feces | 39.0 | | 17.7 | 8.5 | 8.1 | 4.7 |
| Amount utilized | | | 322.6 | 252.3 | 598.7 | 44.9 |
| Per cent utilized | | | 94.8 | 96.7 | 98.7 | 90.5 |
| **Experiment No. 538, subject C. J. W.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,331.0 | 917.4 | 230.8 | 151.9 | | 30.9 |
| Potato | 452.0 | 341.3 | 11.3 | 0.4 | 94.5 | 4.5 |
| Crackers | 202.0 | 13.9 | 16.4 | 27.1 | 143.0 | 1.6 |
| Fruit | 944.0 | 798.6 | 3.8 | 4.7 | 134.1 | 2.8 |
| Sugar | 12.0 | | | | 12.0 | |
| Total food consumed | 2,941.0 | 2,071.2 | 262.3 | 184.1 | 383.6 | 39.8 |
| Feces | 65.0 | | 27.7 | 13.9 | 14.9 | 8.5 |
| Amount utilized | | | 234.6 | 170.2 | 368.7 | 31.3 |
| Per cent utilized | | | 89.4 | 92.4 | 96.1 | 78.6 |
| **Experiment No. 547, subject H. R. G.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,142.0 | 762.2 | 219.7 | 132.2 | | 27.9 |
| Potato | 425.0 | 320.9 | 10.6 | 0.4 | 88.8 | 4.3 |
| Crackers | 343.0 | 23.7 | 27.8 | 46.0 | 242.8 | 2.7 |
| Fruit | 599.0 | 506.8 | 2.4 | 3.0 | 85.0 | 1.8 |
| Sugar | | | | | | |
| Total food consumed | 2,509.0 | 1,613.6 | 260.5 | 181.6 | 416.6 | 36.7 |
| Feces | 49.0 | | 26.7 | 7.6 | 9.7 | 5.0 |
| Amount utilized | | | 233.8 | 174.0 | 406.9 | 31.7 |
| Per cent utilized | | | 89.8 | 95.8 | 97.7 | 86.4 |

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[1] Jour. Biol. Chem., 16 (1913), No. 3, pp. 389-393.

*Data of digestion experiments with grayfish in a simple mixed diet*—Continued.

| Experiment, subject, and diet | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbo-hydrates. | Ash. |
| **Experiment No. 548, subject A. J. H.:** | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Grayfish (in form of fish loaf) | 1,097.0 | 732.1 | 211.1 | 127.0 | ........ | 26.8 |
| Potato | ........ | ........ | ........ | ........ | ........ | ........ |
| Crackers | 76.0 | 5.2 | 6.2 | 10.2 | 53.8 | 0.6 |
| Fruit | 168.0 | 142.1 | 0.7 | 0.8 | 23.9 | 0.5 |
| Sugar | 4.0 | ........ | ........ | ........ | 4.0 | ........ |
| Total food consumed | 1,345.0 | 879.4 | 218.0 | 138.0 | 81.7 | 27.9 |
| Feces | 19.0 | ........ | 6.5 | 5.7 | 3.7 | 3.1 |
| Amount utilized | ........ | ........ | 211.5 | 132.3 | 78.0 | 24.8 |
| Per cent utilized | ........ | ........ | 97.0 | 95.9 | 95.5 | 88.9 |
| **Experiment No. 549, subject P. K.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,634.0 | 1,090.5 | 314.4 | 189.2 | ........ | 39.9 |
| Potato | 500.0 | 377.5 | 12.5 | 0.5 | 104.5 | 5.0 |
| Crackers | 463.0 | 32.0 | 37.5 | 62.0 | 327.8 | 3.7 |
| Fruit | 926.0 | 783.4 | 3.7 | 4.6 | 131.5 | 2.8 |
| Sugar | ........ | ........ | ........ | ........ | ........ | ........ |
| Total food consumed | 3,523.0 | 2,283.4 | 368.1 | 256.3 | 563.8 | 51.4 |
| Feces | 36.0 | ........ | 15.4 | 9.9 | 6.1 | 4.6 |
| Amount utilized | ........ | ........ | 352.7 | 246.4 | 557.7 | 46.8 |
| Per cent utilized | ........ | ........ | 95.8 | 96.1 | 98.9 | 91.1 |
| **Experiment No. 579, subject P. K.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,175.0 | 773.7 | 230.5 | 153.0 | ........ | 17.8 |
| Potato | 434.0 | 327.7 | 10.9 | 0.4 | 90.7 | 4.3 |
| Crackers | 416.0 | 28.7 | 33.7 | 55.8 | 294.5 | 3.3 |
| Fruit | 1,038.0 | 878.1 | 4.2 | 5.2 | 147.4 | 3.1 |
| Sugar | 35.0 | ........ | ........ | ........ | 35.0 | ........ |
| Total food consumed | 3,098.0 | 2,008.2 | 279.3 | 214.4 | 567.6 | 28.5 |
| Feces | 34.0 | ........ | 13.6 | 10.0 | 5.9 | 4.5 |
| Amount utilized | ........ | ........ | 265.7 | 204.4 | 561.7 | 24.0 |
| Per cent utilized | ........ | ........ | 95.1 | 95.3 | 99.0 | 84.2 |
| **Experiment No. 580, subject C. J. W.:** | | | | | | |
| Grayfish (in form of fish loaf) | 1,151.0 | 757.9 | 225.8 | 149.9 | ........ | 17.4 |
| Potato | 462.0 | 348.8 | 11.5 | 0.5 | 96.6 | 4.6 |
| Crackers | 185.0 | 12.7 | 15.0 | 24.8 | 131.0 | 1.5 |
| Fruit | 1,168.0 | 988.1 | 4.7 | 5.8 | 165.9 | 3.5 |
| Sugar | 112.0 | ........ | ........ | ........ | 112.0 | ........ |
| Total food consumed | 3,078.0 | 2,107.5 | 257.0 | 181.0 | 505.5 | 27.0 |
| Feces | 58.0 | ........ | 22.8 | 15.5 | 11.5 | 8.2 |
| Amount utilized | ........ | ........ | 234.2 | 165.5 | 494.0 | 18.8 |
| Per cent utilized | ........ | ........ | 91.1 | 91.4 | 97.7 | 69.6 |
| Average food consumed per subject per day | 954.9 | 629.6 | 94.9 | 68.1 | 149.7 | 12.6 |

*Summary of digestion experiments with grayfish in a simple mixed diet.*

| Experiment No. | Subject. | Protein. | Fat. | Carbo-hydrates. | Ash. |
|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 535 | H. R. G. | 87.0 | 96.6 | 96.7 | 91.5 |
| 537 | P. K. | 94.8 | 96.7 | 98.7 | 90.5 |
| 538 | C. J. W. | 89.4 | 92.4 | 96.1 | 78.6 |
| 547 | H. R. G. | 89.8 | 95.8 | 97.7 | 86.4 |
| 548 | A. J. H. | 97.0 | 95.9 | 95.5 | 88.9 |
| 549 | P. K. | 95.8 | 96.1 | 98.9 | 91.1 |
| 579 | P. K. | 95.1 | 95.3 | 99.0 | 84.2 |
| 580 | C. J. W. | 91.1 | 91.4 | 97.7 | 69.6 |
| | Average | 92.5 | 95.0 | 97.5 | 85.1 |

Considering the diet as a whole, 95 grams of protein, 68 grams of fat, and 150 grams of carbohydrates were eaten per day, of which 92.5 per cent of the protein, 95 per cent of the fat, and 97.5 per cent of the carbohydrates were digested. The fuel value of the diet was 1,592 calories. The estimated digestibility of grayfish protein and fat as obtained by making allowance for the unutilized protein and fat resulting from the accessory foods of the diet are 92.8 per cent and 94.3 per cent, respectively.

The four different subjects who assisted in the eight experiments conducted to determine the digestibility of grayfish ate on an average 440 grams of grayfish daily as compared with 471 grams of butterfish, 448 grams of mackerel, and 355 grams of salmon, which would indicate that this fish was eaten with as much relish as the other fish studied.

## SALMON.

Since difficulty was experienced in securing fresh salmon for the purpose of this investigation, a good grade of canned salmon (Chinook salmon, *Oncorhynchus tschawytscha*) was used instead in the experiments here reported. The canned salmon was purchased without regard to any commercial brand from a wholesale grocer, and was taken to represent this type of fish in general use.

The results obtained in three-day test periods with salmon are given in the table which follows:

*Data of digestion experiments with salmon in a simple mixed diet.*

| Experiment, subject, and diet | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
| Experiment No. 561, subject H. R. G.: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Salmon (in form of fish loaf) | 1,004.0 | 621.8 | 249.8 | 108.8 | | 23.6 |
| Potato | 411.0 | 310.3 | 10.3 | 0.4 | 85.9 | 4.1 |
| Crackers | 297.0 | 20.5 | 24.0 | 39.8 | 210.3 | 2.4 |
| Fruit | 514.0 | 434.8 | 2.1 | 2.6 | 73.0 | 1.5 |
| Sugar | 23.0 | | | | 23.0 | |
| Total food consumed | 2,249.0 | 1,387.4 | 286.2 | 151.6 | 392.2 | 31.6 |
| Feces | 46.0 | | 23.3 | 4.7 | 13.5 | 4.5 |
| Amount utilized | | | 262.9 | 146.9 | 378.7 | 27.1 |
| Per cent utilized | | | 91.9 | 96.9 | 96.6 | 85.8 |
| Experiment No. 562, subject A. J. H.: | | | | | | |
| Salmon (in form of fish loaf) | 854.0 | 528.9 | 212.5 | 92.5 | | 20.1 |
| Potato | | | | | | |
| Crackers | 104.0 | 7.2 | 8.4 | 14.0 | 73.6 | 0.8 |
| Fruit | 103.0 | 87.2 | 0.4 | 0.5 | 14.6 | 0.3 |
| Sugar | 24.0 | | | | 24.0 | |
| Total food consumed | 1,085.0 | 623.3 | 221.3 | 107.0 | 112.2 | 21.2 |
| Feces | 42.0 | | 18.3 | 12.1 | 6.7 | 4.9 |
| Amount utilized | | | 203.0 | 94.9 | 105.5 | 16.3 |
| Per cent utilized | | | 91.7 | 88.7 | 94.0 | 76.9 |

*Data of digestion experiments with salmon in a simple mixed diet*—Continued.

| Experiment, subject, and diet. | Weight of food. | Constituents of foods. | | | | |
|---|---|---|---|---|---|---|
| | | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
| Experiment No. 563, subject P. K.: | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* | *Grams.* |
| Salmon (in form of fish loaf) | 1,286.0 | 796.4 | 320.0 | 139.4 | | 30.2 |
| Potato | 553.0 | 417.5 | 13.8 | 0.6 | 115.6 | 5.5 |
| Crackers | 325.0 | 22.4 | 26.3 | 43.6 | 230.1 | 2.6 |
| Fruit | 717.0 | 606.6 | 2.9 | 3.6 | 101.8 | 2.1 |
| Sugar | 60.0 | | | | 60.0 | |
| Total food consumed | 2,941.0 | 1,842.9 | 363.0 | 187.2 | 507.5 | 40.4 |
| Feces | 49.0 | | 16.4 | 6.2 | 19.1 | 7.3 |
| Amount utilized | | | 346.6 | 181.0 | 488.4 | 33.1 |
| Per cent utilized | | | 95.5 | 96.7 | 96.2 | 81.9 |
| Experiment No. 564, subject C. J. W.: | | | | | | |
| Salmon (in form of fish loaf) | 1,115.0 | 690.5 | 277.4 | 120.9 | | 26.2 |
| Potato | 431.0 | 325.4 | 10.8 | 0.4 | 90.1 | 4.3 |
| Crackers | 177.0 | 12.2 | 14.4 | 23.7 | 125.3 | 1.4 |
| Fruit | 842.0 | 712.3 | 3.4 | 4.2 | 119.6 | 2.5 |
| Sugar | 105.0 | | | | 105.0 | |
| Total food consumed | 2,670.0 | 1,740.4 | 306.0 | 149.2 | 440.0 | 34.4 |
| Feces | 56.0 | | 23.6 | 7.4 | 18.4 | 6.6 |
| Amount utilized | | | 282.4 | 141.8 | 421.6 | 27.8 |
| Per cent utilized | | | 92.3 | 95.0 | 95.8 | 80.8 |
| Average food consumed per subject per day | 745.4 | 466.2 | 98.0 | 49.6 | 121.0 | 10.6 |

*Summary of digestion experiments with salmon in a simple mixed diet.*

| Experiment No. | Subject. | Protein. | Fat. | Carbohydrates. | Ash. |
|---|---|---|---|---|---|
| | | *Per cent.* | *Per cent.* | *Per cent.* | *Per cent.* |
| 561 | H. R. G. | 91.9 | 96.9 | 96.6 | 85.8 |
| 562 | A. J. H. | 91.7 | 88.7 | 94.0 | 76.9 |
| 563 | P. K. | 95.5 | 96.7 | 96.2 | 81.9 |
| 564 | C. J. W. | 92.3 | 95.0 | 95.8 | 80.8 |
| | Average | 92.9 | 94.3 | 95.7 | 81.4 |

In the test periods in which canned salmon was included in the experimental ration, the subjects ate an average of 355 grams of salmon daily. The total diet eaten supplied 98 grams of protein, 50 grams of fat, and 121 grams of carbohydrates per day, and the coefficients of digestibility were found to be 92.9 per cent for protein, 94.3 per cent for fat, and 95.7 per cent for carbohydrates. The fuel value of the diet was 1,326 calories. When allowance is made for the undigested protein and fat residues occurring in the feces resulting from the accessory foods of the diet, the digestibility for the protein and fat of salmon is found to be 93.2 per cent and 93.7 per cent, respectively, and indicates that salmon is very completely utilized by the human body.

## SUMMARY.

In the study of the digestibility of the protein and fat supplied by some common varieties, fish in the form of "fish loaf" was served as the major part of a simple mixed diet, which also included potatoes, crackers, fruit, sugar, and tea or coffee. The principal results are summarized in the following table:

*Summary of results of all digestion experiments.*

| Number of experiments. | Kind of fish. | Average amount of fish eaten per man per day. | Digestibility of fish protein. | Digestibility of fish fat. |
|---|---|---|---|---|
| | | *Grams.* | *Per cent.* | *Per cent.* |
| 3 | Mackerel | 448 | 93.1 | 95.2 |
| 3 | Butterfish | 471 | 91.9 | 86.4 |
| 8 | Grayfish | 440 | 92.8 | 94.3 |
| 4 | Salmon | 355 | 93.2 | 93.7 |

On an average, the subjects ate 448 grams of Boston mackerel, 471 grams of butterfish, 440 grams of grayfish, and 355 grams of salmon daily, which would indicate that in every case the fish was eaten with relish.

Considering the experiments as a whole, the total diet supplied on an average 99 grams of protein, 60 grams of fat, and 160 grams of carbohydrates daily, the fuel value being 1,576 calories. The low amount of fat and of carbohydrates was due to the fact that butter and similar fat were omitted and the foods other than fish loaf which supplied both protein and carbohydrates, were limited in order that both the fat and the protein in the diet might be contributed in as large proportion as possible by the fish.

The average coefficients of digestibility for fish proteins were: Boston mackerel, 93.1 per cent; butterfish, 91.9 per cent; grayfish, 92.8 per cent; and salmon, 93.2 per cent. In view of the close agreement, it would seem, from a dietetic standpoint, that the different fishes studied would supply protein in equally available form.

The average coefficients of digestibility of the fish fats were found to be as follows: Boston mackerel, 95.2 per cent; butterfish, 86.4 per cent; grayfish, 94.3 per cent; and salmon, 93.7 per cent. As these figures show, the fats were well assimilated in the case of the mackerel, grayfish, and salmon, which, according to the usual custom, are to be regarded as "fat fishes." Considering the experiments as a whole, the very complete utilization of the protein and fat supplied by the fishes studied offer additional experimental evidence that fish is a very valuable food and that its extensive use in the dietary is especially desirable.

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